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Black-headed budworm

UNITED STATES DEPARTMENT OF AGRICULTURE

FOREST SERVICE

Progress Report

STUDIES OF THE BIOLOGY AND CONTROL OF THE BLACK-HEADED BUDWORM IN ALASKA

Season of 1954

by

W. F. McCambridge

Alaska Forest Research Center
R. F. Taylor, Forester in Charge
Juneau, Alaska
March 1955

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Office Memorandum · UNITED STATES GOVERNMENT

TO : Director, PNW Station DATE: August 15, 1955

FROM : R. F. Taylor, Forester in Charge

SUBJECT: RX-AL-RESEARCH PROGRAM, Progress Report. Studies of the Biology and Control of the Black-headed Budworm in Alaska - 1954.

In regard to your letter of June 22 concerning the causes of the black-headed budworm decline, we cannot add much to the data presented in the 1954 report on the biology and control of the budworm.

RWC RLT

McCambridge feels that parasites were largely responsible for decline of budworm populations. It appears that Microgaster peroneae; a chalcid parasite, family Eulophidae; Itoplectis quadricingulatus Cush. and the dipterous parasite Actia diffidens, were the principle parasites controlling the budworm in 1954.

It has been impossible to collect black-headed budworm larvae in any quantity this year. Almost all of the late instar larvae that have been collected were infested with parasites.

As was the case in 1954, disease has not been evident this year although some amount is suspected.

R F Taylor

FOREST SERVICE
PACIFIC NORTHWEST EXPERIMENT STATION
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RECEIVED

Attach to McCambridge's report of March on biology and control of black-headed budworm. Our June 22 memo merely raised the question of what is controlling the budworm.

RLT
8/17/55

BMNRI 1319 ✓

R. F. Taylor, Alaska Forest Research Center
Juneau, Alaska

June 22, 1955

R. W. Cowlin, Director By:

RX-NW RESEARCH PROGRAM, Progress Report
Studies of the Biology and Control of the Black-Headed Budworm in Alaska

McCambridge's progress report of March, 1955 on studies of the biology and control of the black-headed budworm has gone the rounds of our Forest Insect Research staff. They all feel that Mac did a good job of collecting field data and reporting his findings.

We noted that the budworm outbreak is declining but failed to find specific comment by McCambridge regarding the cause of the decline. Are his data sufficient to indicate what is controlling the budworm?

RLFurniss:nw

RLF

1955

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Progress Report

STUDIES OF THE BIOLOGY AND CONTROL OF THE BLACK-HEADED BUDWORM IN ALASKA

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by

W. F. McCambridge

1/ The work described herein was carried out between June and September of 1954. The men who conducted the field work follow: Arthur B. Flick, Jr., George H. Sherrick, David G. Wagstaff.

Alaska Forest Research Center
R. F. Taylor, Forester in Charge
Juneau, Alaska
March 1955

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STUDIES OF THE BIOLOGY AND CONTROL OF THE BLACK-HEADED BUDWORM IN ALASKA

Season of 1954

by
W. F. McCambridge

SUMMARY

Studies of the biology and control of the black-headed budworm in Alaska were initiated in 1953 in order to interpret survey data and develop efficient and logical survey methods. Major emphases of the work carried on that year were directed toward determining the life history of the budworm, its feeding habits, susceptibility to artificial control and importance and kinds of natural control agents. Incidental studies were continued during 1954 with emphases placed on limited life history checks, budworm damage, limited artificial control refinements and more intensive investigation of the natural control agents.

Results of the 1954 investigations are summarized below:

(1) Average maximum temperatures were three to four degrees lower in 1954 than in 1953 during May, June and July. These temperature reductions coupled with considerable rain are believed to have contributed to retarding budworm development by one month.

(2) Budworm fecundity remained constant as the outbreak continued to die down.

(3) One year of heavy budworm defoliation on hemlock second-growth caused top kill in 81.5 percent of the dominant hemlock trees, 71.1 percent of codominants and 23.3 percent of the intermediates. The average length of top kill for the dominant and codominant trees was 2' and 1½' respectively.

(4) One year of heavy budworm defoliation on Sitka spruce second-growth caused leader kill in 86 percent of the dominant spruce trees, 71 percent of the codominants, 71 percent of the intermediates, and 29 percent of the suppressed spruce. All current year's growth was defoliated throughout the top 16' of the dominant spruce, the top 8' of codominant spruce, and the top 4' of the intermediate spruce.

(5) Heavy, but not extreme, black-headed budworm damage to mature western hemlock stands caused top kill in 21 percent of the codominant crowns and 14 percent of the intermediates. This top kill averaged 12 feet and 5 feet respectively.

(6) The tops of hemlock were broken or forked previous to the present budworm infestation on 44 percent of the dominant trees, 23 percent of the codominants and 14 percent of the intermediates. Some of this old damage is believed to be evidence of previous budworm attack.

(7) Small-scale insecticide tests against black-headed budworm eggs show that 4 percent nicotine sulphate and 2 percent "Kleenup Soluable" will give satisfactory kill. Practical field tests should now be conducted using these two insecticides.

(8) Hymenopterous and dipterous parasites continue to be reliable control agents of the budworm epidemic. Disease did not appear as a significant controlling force in the Juneau area in 1954, although in 1953 it was very effective in some areas.

INTRODUCTION

The black-headed budworm, Acleris variana Fern., outbreak which has raged throughout portions of the Tongass National Forest during the past seven years stimulated a great deal of interest and concern regarding the possible destruction of standing timber in Southeast Alaska. Lacking basic information with which to interpret and evaluate survey data concerning rate of spread, damage, and trend, studies were initiated during the summer of 1953 to supply fundamental information on the budworm.[1/] Supplied with these data, investigations were continued in 1954 to determine how serious budworm feeding was to hemlock growth, to refine artificial control treatments, to measure the effects of natural control agents, and to continue certain biological investigations which were started in 1953.

Studies of natural control agents, artificial control refinements, effects of budworm defoliation on advanced reproduction, and biology were carried on in Juneau. Limited studies of the effects of repeated budworm feeding on mature hemlock and spruce were carried out at Petersburg. All in all, these data collected aid materially in the collection and interpretation of the annual budworm survey data.

1/ Results of this work have been written up in an unpublished report titled "Studies of the Biology, Habits and Control of the Black-headed Budworm in Alaska, Season of 1953". This was a joint report of the Pacific Northwest Forest and Range Experiment Station and the Alaska Forest Research Center.

BIOLOGY

Life History

A cold wet spring and early summer prolonged budworm larval development by one month compared to the speed of development in 1953. Average maximum temperatures were between 3 and 4 Fahrenheit degrees lower in 1954 than in 1953 during May, June and July. For August, 1954, the average maximum temperature was 4 degrees higher than for the same month in 1953. This fact was no doubt responsible for some of the increase in rate of budworm development between pupation and oviposition. At oviposition, budworm development was only two weeks behind the 1953 period.

The following tables present the rate of larval development and a comparison of budworm development during 1953 and 1954.

Table 1.--Rate of black-headed budworm larval development in Juneau, 1954.

Date	Budworm stage shown in percent					
	Eggs	Instars				Pupae
		1	2	3	4	5	
May 26	100.0						
June 3	95.0	5.0					
June 11	—	—	—				
June 21		10.0	90.0				
June 28			5.0	95.0			
July 12			5.0	64.0	31.0		
July 19				43.5	30.5	26.0	
July 26				25.0	55.0	20.0	
Aug. 2						—	
Aug. 9						80.0	20.0

Table 2.--Comparison of black-headed budworm life history data, 1953-and 1954, Juneau.

	1953	1954
Eggs hatching	May 29	June 2
5th instar reached	June 21	July 19
Pupation	July 11	Aug. 6
Moths emerging	July 31	Aug. 17
Eggs deposited	Sept. 1	Sept. 15

HABITS

Egg-laying habits

Fecundity-As the black-headed budworm outbreak subsided in the Juneau area, an attempt was made to determine if this recession could be detected in budworm fecundity. Caging tests were carried out in 1953 and again this year. Some refinements in the technique were made which are believed responsible for a threefold increase in average egg deposition. (Nine eggs per female in 1953; twenty-seven eggs per female in 1954.) These refinements consisted in using wire screening for the floors of the cages in place of muslin, and secondly, in using the most recently emerged males.

As in 1953, twenty small hemlock trees were cleaned of budworms and caged. The cages were made of muslin with the exception of one side and the bottom which were made of standard window screening. One pair of moths was placed in each cage and the following results obtained.

Table 3.--Black-headed budworm egg production on small caged hemlock trees, Juneau, 1954.

Cage No.	Emergence date		Moths caged	Egg counts made	Number of eggs
	Male	Female			
	August		August	September	
1	26	30	31	26	0
2	28	30	31	30	45
3	28	30	31	30	42
4	29	30	31	Cage broken	—
5	29	30	31	30	19
6	30	30	31	30	11
7	30	30	31	30	0
8	30	30	31	30	96
9	30	30	31	Oct. 11	0
10	30	30	31	Cage broken	—
	September		September		
11	2	3	4	Oct. 8	14
12	3	2	4	Sept. 30	14
13	2	3	4	Sept. 30	35
14	3	3	4	Sept. 30	11
15	3	2	4	Sept. 30	34
16	3	3	4	Oct. 4	52
17	2	2	4	Sept. 30	41
18	2	3	4	Oct. 25	3
19	3	3	4	Oct. 4	36
20	3	3	4	Oct. 15	38

Males died shortly after mating, while females remained alive, often in an apparent inactive stage, for many days after oviposition seemed completed.

During the course of other lines of investigation some miscellaneous impressions were obtained on budworm habits which appear worthy of mention.

1. Buds on heavily infested hemlock were found to contain as many as 4 to 5 budworm larvae each. In all such cases, larvae were in the first or early second instar. One larva per bud is typical and two larvae per bud are faily common.

2. The size of feeding larvae seems to increase from the top branches down and from the tips inward on the laterals.

3. Trees heavily defoliated in 1953 contained larvae less advanced in growth than were found on healthier trees - those less heavily defoliated in 1953.

DAMAGE

Black-headed budworm feeding on the Tongass National Forest has been extensive and alarming for the past several years. Hemlock and spruce have been defoliated and no age groups have been spared. Despite the heavy defoliation practically no tree mortality has occurred and questions arise as to just how serious the budworm outbreak is and has been.

In order to answer some of these questions, studies were initiated in 1954 to determine: (a) what effects heavy budworm defoliation had on young hemlock and spruce second-growth; and (b) what effects growth rate, crown position, species composition, site and exposure had on susceptibility of mature hemlock to budworm defoliation. Such studies are of necessity long-term, but some interesting information has been obtained which is reported on here pending completion of the investigations.

Effects of heavy budworm defoliation on young stands of hemlock and spruce

History of defoliation-Black-headed budworm defoliation occurred on the study plots near Juneau and Douglas during the summer of 1953 only. Budworm egg population samples taken in the vicinity of the plots showed egg densities on hemlock needles of 2.27 eggs per twig inch of needles. These population samples were taken from the upper crowns of open-grown advanced hemlock reproduction. Mortality by parasites during the egg and larval periods was not noticeably excessive and symptoms of disease were uncommon.

Hemlock plot.--Approximately 30 years ago 2½ acres of mature hemlock forest were clearcut near the mouth of Lemon Creek. The reproduction which came back on this southwest-facing slope is almost 100 percent

hemlock. Within this stand a one-tenth acre circular plot was established on a semi-permanent basis with all trees 1" d.b.h. and larger numbered and tagged to facilitate study of budworm feeding. The data presented in the following tables summarize the condition of the hemlock plot in 1954 after very heavy budworm feeding in 1953. Height of trees in this first table includes dead tops caused by the 1953 feeding.

Table 4.--Tabulation of hemlock characteristics, Lemon Creek plot, Juneau 1954.

	Western Hemlock					Sitka Spruce				
	Crown Class					Crown Class				
	Dom.	Co-dom.	Int.	Supp.	Total	Dom.	Co-dom.	Int.	Supp.	Total
No. of trees	54	45	107	122	328	0	1	3	6	10
Age at 1 foot 1/	27	27	26	25						
Ave. d.b.h.	4.2"	3.5"	2.3"	1.5"						
Ave. tree height	27'3"	24'0"	20'8"	16'4"						
Growth rate-rings 1/ per inch of radius	10	12.3	17.8	21.1						

1/ Based on a sample of 10 trees in each crown class.

Budworm feeding on the plot was so light in 1954 that it can be ignored. The following table presents the effects of the heavy budworm feeding, all of which occurred in 1953.

Table 5.--Effects of one year of heavy feeding by the black-headed budworm on young hemlock second-growth, Lemon Creek plot, Juneau, 1954.

	Western Hemlock					Sitka Spruce				
	Crown Class					Crown Class				
	Dom.	Co-dom.	Int.	Supp.	Total	Dom.	Co-dom.	Int.	Supp.	Total
Length of top kill 1/	2'	1'7"	0.5"	2.8"		--	0	0	0	
Percent of stems top killed	81.5	71.1	23.3	2.4						
Diam. at base of dead section 1/	.5"	.4"	--	--						
Ave. length of complete defoliation	6'6"	3'6"	1'0"	0'2"		--	0	0	0	
Percent of stems having complete defoliation	92.6	82.2	28.9	5.0						

1/ Based on a sample of 10 trees in each crown class.

Graphs of radial growth since 1950 for each crown class were constructed. It is evident from study of these graphs that radial growth showed a marked decrease in 1953, the year of heavy budworm defoliation.

However, in the upper three crown classes growth was even more sharply reduced in 1954, a year when budworm feeding was negligible. This radial growth reduction may be due in part to a carry-over effect from the previous year's defoliation, or it could be normal for the year.

Black-headed budworm feeding in 1953 reduced dominant and co-dominant leader growth that year by 78 percent compared to the length of 1952 growth. The high percentage of dead tops produced in these two classes is further reflected in a continued reduction in leader growth during 1954. On the other hand, intemediate crowns which suffered little top kill show a remarkable recovery in average length of leader growth and if the present trend continues some of these intermediate trees may outgrow trees now classed as codominant. Suppressed trees show no recovery in leader growth despite insignificant defoliation.

It is interesting to note that complete defoliation extends down to a fairly even height. By subtracting average length of complete defoliation from tree height in each crown class it is seen that foliage was devoured down to a height of approximately 20 feet: dominant 20'9", codominant 20'6", intermediate 19'8", and suppressed 16'2".

A number of negative or neutral impressions are gained from a study of the data collected on the hemlock second-growth plot. They are:

a. There appears little if any correlation between the length of 1952 leader growth and the amount of top kill produced in 1953.

b. There appears little if any correlation between the length of 1952 leader growth and the length of complete defoliation in 1953.

c. There appears little if any correlation between the rate of diameter growth and the amount of top kill.

d. No particular tree characteristics were detected which might explain why 18.5 percent of the dominant trees contained no top kill, or why 7.4 percent of the dominant trees had not been noticeably defoliated.

It is planned to continue this study of the effects of budworm defoliation on hemlock second-growth until it is felt that the stand has fully recovered from the budworm epidemic.

Sitka spruce plot.—Between 40 and 45 years ago, land in the town of Douglas that had been cleared for building, or for firewood or other purposes was allowed to revert back to a forest condition. Sitka spruce became the dominating tree species mixed with some hemlock, much alder and shrubs. Stand density is variable throughout the area. In order to see all of the trees, the one-tenth acre study plot was placed in a fairly sparse spruce stand, but one which is typical of much of the spruce south and west of Douglas. The plot is at an elevation of about 100 feet and has a northeast exposure.

Budworm feeding occurred on and around the plot in 1953 only. During that summer the whole hillside south of Douglas was brown and defoliation was most spectacular and caused considerable alarm. In the discussion that follows some specific details of damage caused by the 1953 defoliation are presented. It should be pointed out that the study is not concluded, and that the present information is not complete or final.

In the following table data collected in 1954 are presented to furnish information on the general stand characteristics. For all practical purposes, these characteristics are similar to those present in 1953 when the spruce was undergoing defoliation by the budworm.

Table 6.—Tabulation of Sitka spruce characteristics, Douglas plot, 1954.

	Sitka Spruce					Western Hemlock				
	Crown Class					Crown Class				
	Dom.	Co-dom.	Int.	Supp.	Total	Dom.	Co-dom.	Int.	Supp.	Total
No. of trees	14	7	14	7	42	0	0	3	1	4
Age at 1 foot	38.5 1/		34 1/	23						
Ave. d.b.h.	8.5"	6.0"	4.1"	2.1"	—	—	—	5.1"	2.4"	
Ave. height	38'	31'	22'	14'	—	—	—	26'	21'	
Growth rate-rings per inch of radius	8.7 1/		8.5 1/	9.2						

1/ Based on a sample of 10 trees.

Budworm feeding on the plot during 1954 was negligible so that all of the damage recorded here can be attributed to 1953 defoliation. The effects of heavy budworm feeding are presented in tabular form below. Unless otherwise stated, all length measurements are from the top of the trees down.

Table 7.—Effects of one year of heavy feeding by the black-headed budworm on young second-growth Sitka spruce, Douglas plot, 1954.

	Sitka Spruce			
	Crown Class			
	Dom.	Co-dom.	Int.	Supp.
Percent of trees with leaders killed	86	71	71	29
Ave. length of crown with all 1953 growth defoliated	16'	8'	4'	.7'
Percent of ave. crown length	49	31	24	8
Ave. crown length suffering some 1953 growth defoliation	25'	14'	10'	2'
Percent of ave. crown length	76	54	60	21
Ave. length of crown with 75% or more total defoliation	10'	7'	3'	0.6'
Percent of ave. crown length	30	27	18	6

During the course of the black-headed budworm outbreak in the Juneau-Douglas area only 1953 spruce growth was killed and it was thought that defoliation was largely confined to 1953 growth. More critical observations regarding defoliation show that at the Douglas spruce plot, 93 percent of the dominant spruce trees suffered some defoliation as far back as the 1951 needle growth. The remaining 7 percent of the dominant spruce showed defoliation of 1952 needle growth. Fifty-seven percent of the codominant spruce trees suffered budworm defoliation as far back as the 1951 foliage. Thirty-six percent of the intermediate spruce contained defoliation as far back as the 1951 foliage, with 57 percent of that crown class suffering defoliation within 1953 and 1952 foliage, and 14 percent of the stems having defoliation in the 1953 growth only.

As was the case with hemlock second-growth, no correlation could be found between radial growth or leader growth and amount of budworm damage. As with hemlock, crown class seems to be the only feature associated proportionately with tree damage.

Radial growth during 1953 was not adversely affected by budworm feeding. However, in 1954 dominant and codominant radial spruce growth was reduced by 44 percent from 1953 growth; intermediate growth by 25 percent; suppressed growth by 10 percent. These growth reductions may or may not be the result of budworm defoliation in 1953.

Effects of growth rate, crown position, species composition, site and exposure on susceptibility of mature hemlock to budworm defoliation.

In setting up the study to determine the effects of certain stand characteristics on susceptibility to budworm defoliation an attempt was made to study paired plots. It soon became evident that truly paired plots are extremely difficult to find, if they exist at all. It also became evident that in a study of this nature, a large number of plots would be needed and that available resources would not be adequate for a complete study. Therefore, the data presented in the following pages will be far from complete, but should provide some insight into the nature of black-headed budworm damage in mature hemlock.

Petersburg was selected as the study area since it had the greatest variety of damaged areas all easily accessible from the town. The plots selected for study are considered representative of typical black-headed budworm damage. They do not represent the extremes of damage, but all are classed as having suffered heavy defoliation and top killing.

Radial growth curves indicate that the budworm outbreak in the Petersburg area began in 1951, with 1952 being the first year of heavy defoliation. Defoliation continued in 1953 but was considerably reduced.

No budworm epidemic could be found in 1954. As with young hemlock and spruce, no correlation was found between growth rate and susceptibility. Increment borings further indicate that growth was declining steadily in the dominant and codominant crowns and the loss of increment caused by the

budworm is insignificant in these crown classes. Growth loss and tree damage is most evident in the tops of the trees, with the dominant and codominant crown classes suffering most heavily. Top kill occurred in 21 percent of the codominant and 14 percent of the intermediate hemlock trees. The average length of top kill was 12 feet and 5 feet respectively in the codominant and intermediate crown classes with diameters at the bases of the killed sections averaging 4 and 2 inches respectively.

Complete defoliation was recorded on 44 percent of the dominant trees, 63 percent of the codominant trees, 35 percent of the intermediate trees and 17 percent of the suppressed trees. Length of this complete defoliation was 26 feet, 22 feet, 12 feet and 4 feet, respectively, with diameters at the bases of defoliated sections averaging 12, 8, 3, and 2 inches, respectively.

The tops were broken or forked previous to the present budworm infestation in 44 percent of the dominant hemlock, in 23 percent of codominants, 14 percent of the intermediates and 2 percent of the suppressed. Some of the broken or forked tops are believed to be evidence of previous budworm attack.

Data from the 8 plots at Petersburg are not adequate to show what affect, if any, species composition has on stand damage caused by budworm feeding. Evidence points toward less damage to individual hemlock as the percentage of spruce of comparable crown class increased.

A strong correlation was found between budworm damage and tree height. The fact that dominant trees in the Petersburg plots do not show greatest defoliation or top kill is due to the small sample of dominant trees available in the old stands comprising the plots.

ARTIFICIAL CONTROL

Small-scale insecticide tests were again carried out against the black-headed budworm. Tests in 1953 showed that low emulsion concentrations of DDT would give very satisfactory control of half-grown larvae. Tests against the egg stage, on the other hand, were not satisfactory, with only nicotine sulphate showing some promise of those insecticides tested.

The tests carried out in 1954 were designed to continue the screening of insecticides to be used against budworm eggs, and also to determine if various DDT emulsions applied prior to egg hatch would remain toxic and thus greatly reduce or prevent budworm damage.

Tests against eggs

Insecticide tests against the egg stage of the budworm were carried out as outlined in the plan of work. In addition to the insecticides listed there, "Kleenup Soluable" was included.

All insecticides were applied on either June 3 or 4. At that time larvae were emerging and head capsules were clearly visible in most of the unhatched eggs. Hemlock buds were well swollen and some had recently opened. All insecticides were applied by a hand sprayer to the underside of the foliage and in such quantity to produce run-off. The results of these tests are summarized below in Table 8.

Table 8.--Relative efficiency of insecticides tested in the field for control of black-headed budworm eggs, Juneau, 1954.

Treatment	No. of eggs sprayed*	Date sprayed	Date examined	No. of unhatched eggs	Percent reduction
2% nicotine sulphate	42	June 3	June 21	39	93
4% nicotine sulphate	42	June 4	June 21	42	100
2% Dendrol	43	June 4	June 21	31	72
4% Dendrol	36	June 4	June 21	30	83
2% nicotine sulphate plus 2% Dendrol	30	June 4	June 21	30	100
2% Kleenup Soluable	27	June 4	June 21	27	100
Check	40	June 4	June 21	3	13

* Sum of the eggs on five twigs; one twig in each of five blocks.

Practical field tests should now be conducted using the 4 percent nicotine sulphate and the 2 percent "Kleenup Soluable" solutions. These tests should involve the treating of entire trees undergoing heavy infestation by the budworm.

Tests to prevent defoliation

Emulsions of DDT were applied to hemlock foliage in early June just prior to the time when budworm eggs began to hatch. It was hoped that the residual action of the insecticide would kill the young larvae as they travelled from the egg case to the bud they would mine and thus prevent damage. In an attempt to prolong the toxic affect of the DDT spray, one series of 8 trees was sprayed with a 12.5 percent DDT emulsion to which had been added 6.4 ounces of linseed oil per gallon of emulsion. Eight trees were sprayed with a standard 12.5 percent DDT emulsion, and eight trees held as checks.

Sprays were applied on June 5. At that time most of the hemlock buds had just opened and some budworm larvae had hatched. On June 29 the trees were examined and while no live larvae could be found on the sprayed trees, all open buds had been killed by the sprays and old foliage had suffered considerable burn. Foliage damage was equally severe with both spray formulations.

Residual toxicity of the two insecticide formulations was tested one month and 6 weeks after spraying. Third and fourth instar larvae were

used and none survived the tests. No difference in toxicity was evident between the two formulations, i.e. the standard 12.5 percent DDT emulsion and the 12.5 percent DDT emulsion to which had been added the linseed oil.

Future insecticide tests to prevent defoliation should be carried out using a lower concentration of DDT and also applying the insecticide as hemlock buds begin to swell.

NATURAL CONTROL FACTORS

Egg parasitism by Trichogramma minutum Riley, was variable in the Juneau area, ranging from 5 to 16 percent. This is an increase from just under 1 percent in 1953 but is far short of parasitism recorded in other areas during the course of this outbreak. Three percent of the eggs examined failed to hatch, while eleven percent of the eggs could not be relocated and are believed destroyed by predators.

Larval collections to determine the amount and causes of mortality were begun in the second instar and carried through to the pupal stage. Results of these collections are presented in tabular form below:

Table 9.—Black-headed budworm mortality in the Juneau area, 1954.

Insect stage	Sample size	Dead when collected Cause unknown	Per-cent	Parasitized Diptera	Parasitized Ichneumonidae	Per-cent
2nd instar	500	84	17	0	10	2
3rd instar	500	43	9	0	94	19
4th instar	500	78	16	9	206	43
5th instar	500	25	5	72	143	43

A total of 948 pupae were collected and placed in rearing capsules. These pupae produced 318 moths (33.5%), 111 parasites (11.7%), of which 55 percent were Itoplectis quadricingulatus Cush., 44 percent were Phaeogenes articus Cush. and 1 percent unknown Hymenoptera. One hundred and twenty of the remaining 519 pupae which gave no emergence were dissected. Found within the pupal cases were: 18 parasites, 24 moths and 78 dry structureless bodies. The remaining 399 pupae are still in rearing capsules in the hope of obtaining additional parasites.

The Dipterous parasite puparia which were taken on fourth and fifth instar larvae are in rearing but to date no adults have been produced.

The Ichneumonid cocoons taken from third, fourth and fifth instar larvae have been placed in rearing and adults are being obtained. To date adults of Eulophidae have emerged from the naked pupae found with dead fourth instar budworm remains. The maximum number of these pupae found in any

one bud with the remains of one budworm larva has been four. Ascogaster sp. has been common on fourth instar budworm larvae.

Since no catch trays were employed in the collecting of budworm larvae for parasite sampling, the percentages of parasitized larvae are low. This is especially true of the fifth instar larvae. Casual examination of budworms in this stage found dropping from trees revealed that most of these larvae were parasitized.

Those larvae tabulated as dead when collected were given careful examination for disease symptoms and a series of each instar sent to Dr. E. A. Steinhaus at the University of California. Patient examination of the material collected in the Juneau area revealed no indication of disease. At Sitka 25 percent of the pupae were dead and spherical cysts of a protozoan were found in the liquified bodies. Since only one collection was made, more specific indentification could not be made.

FURTHER RESEARCH NEEDS

The factors causing natural control, chiefly parasites and disease, require much more study. Unfortunately, budworm populations are now at such low levels at locations having facilities necessary for carrying out studies that research on the budworm in Alaska will be greatly curtailed. The desirability of studying the budworm under endemic conditions is recognized, but greater effort is required under insect population surveys.

The study of budworm damage to young even-aged stands of hemlock and spruce, and the study of damage to mature hemlock will be continued. The effects of temperature and weather on budworm development will be checked. Other than that, no further research on the budworm is contemplated at this time.